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(56) Documents Cited
EP 0944292 A2 DE 010010491 A1 JP 580043699 A
JP 560023097 A US 5793002 A US 4395597 A

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(54) Abstract Title
Partially hollow loudspeaker components

(57) A loudspeaker component such as a diaphragm, surround, suspension or chassis, formed as a one piece moulding in a single material. At least one portion of the component is of a hollow material and at least one other portion is of a solid material (a hollow material includes one with an internal void as well as a material with an internal cellular structure e.g. a foam). The hollow portions are positioned in an acoustically active component to control the acoustic performance of the component e.g. to suppress bell-mode resonance. In the case of a speaker diaphragm, the hollow portions can take the form of annular or radially extending ribs, or can be positioned around the periphery of the diaphragm.

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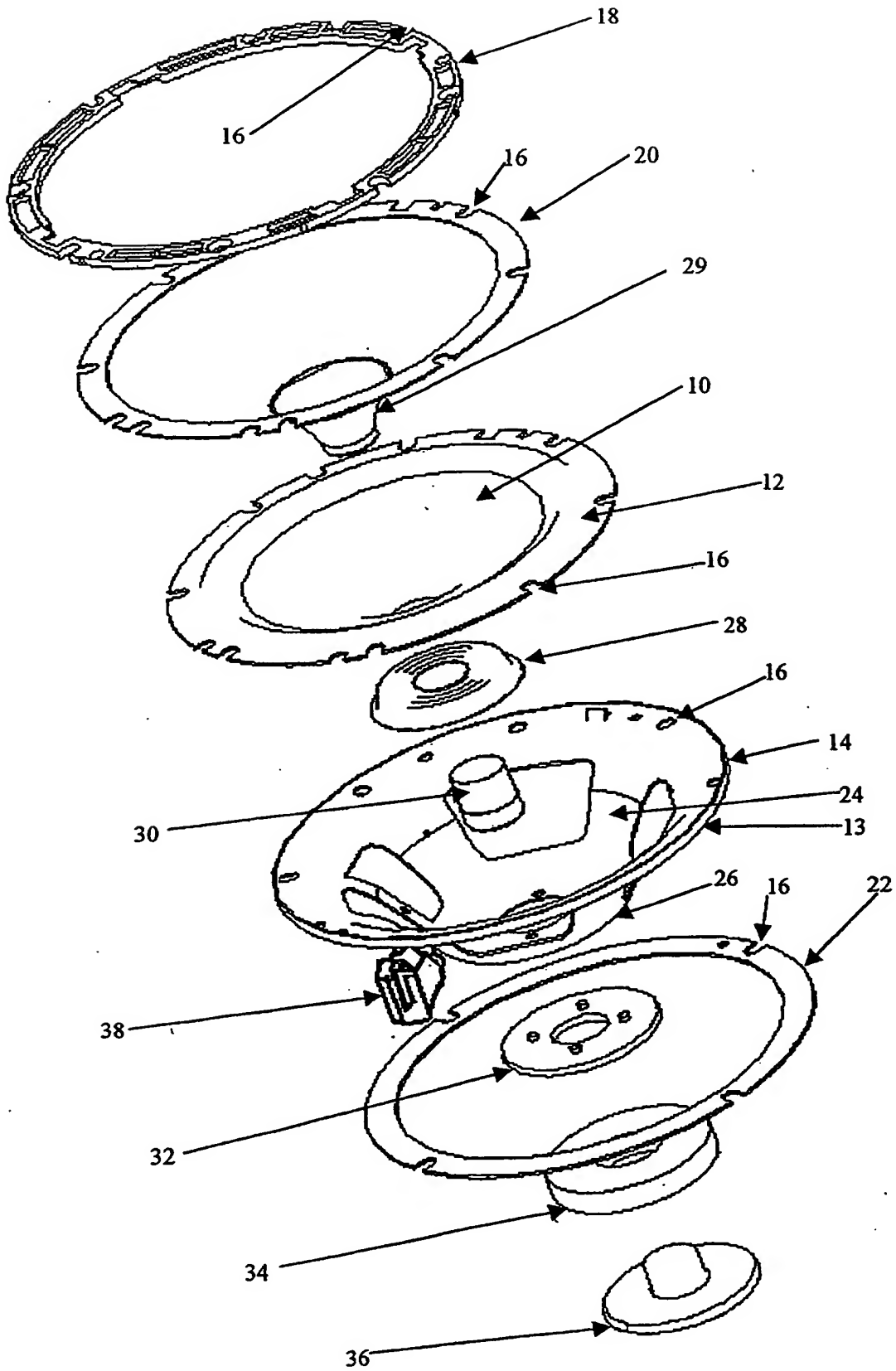

FIGURE 1

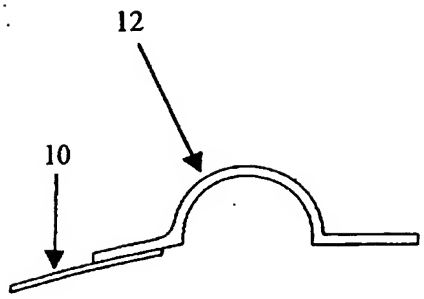

FIGURE 2A

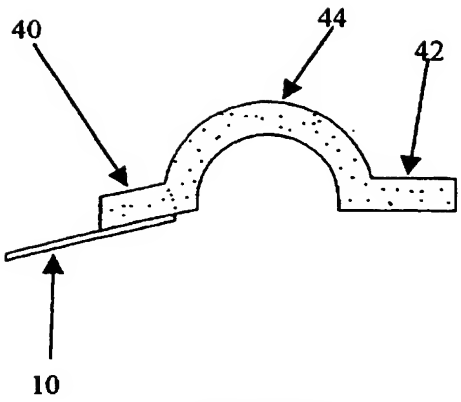

FIGURE 2B

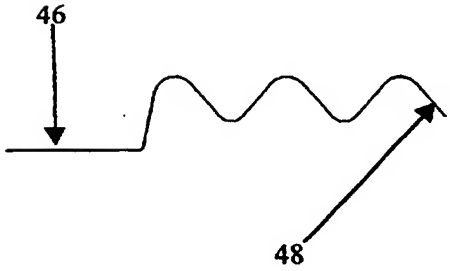

FIGURE 3A

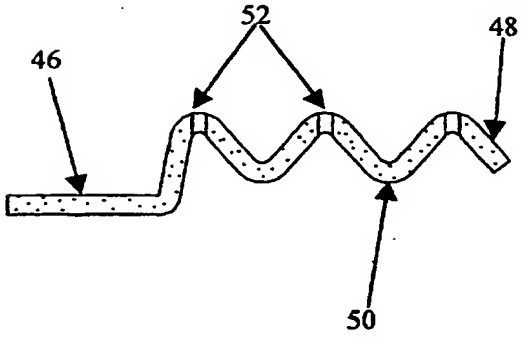

FIGURE 3B

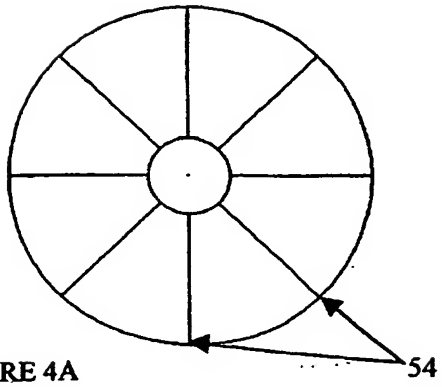

FIGURE 4A

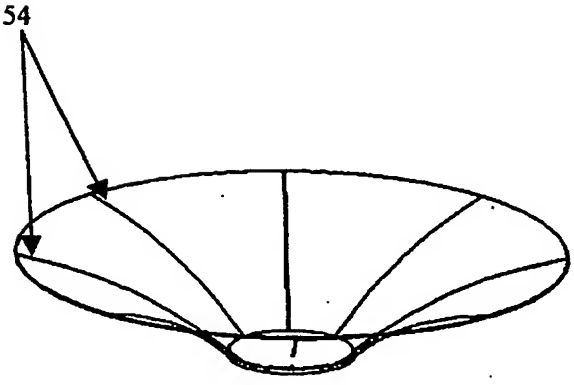

FIGURE 4B

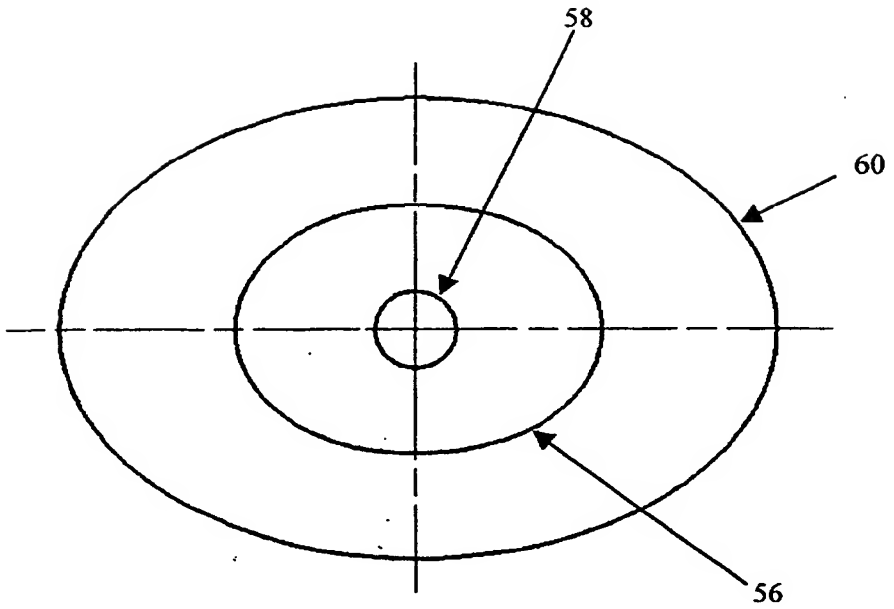

FIGURE 5

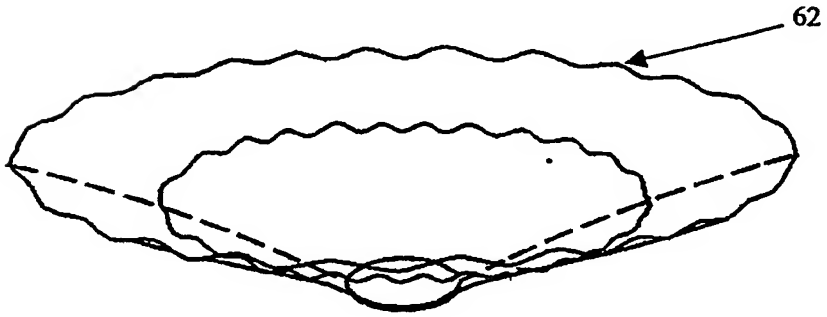

FIGURE 6

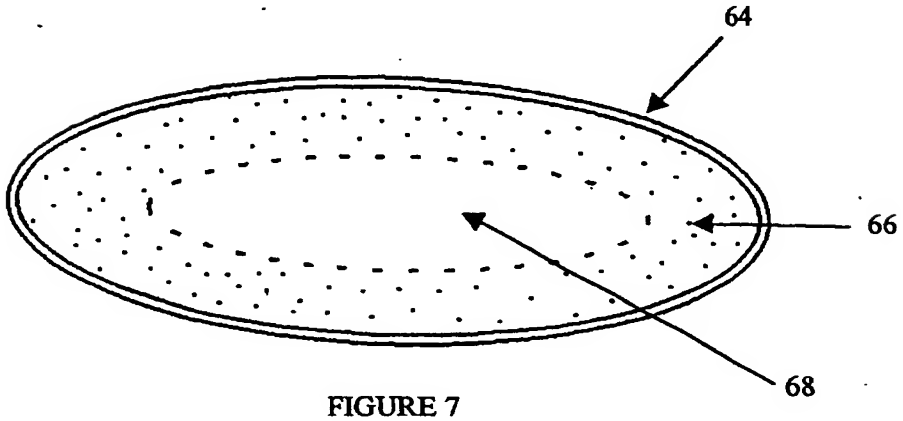

FIGURE 7

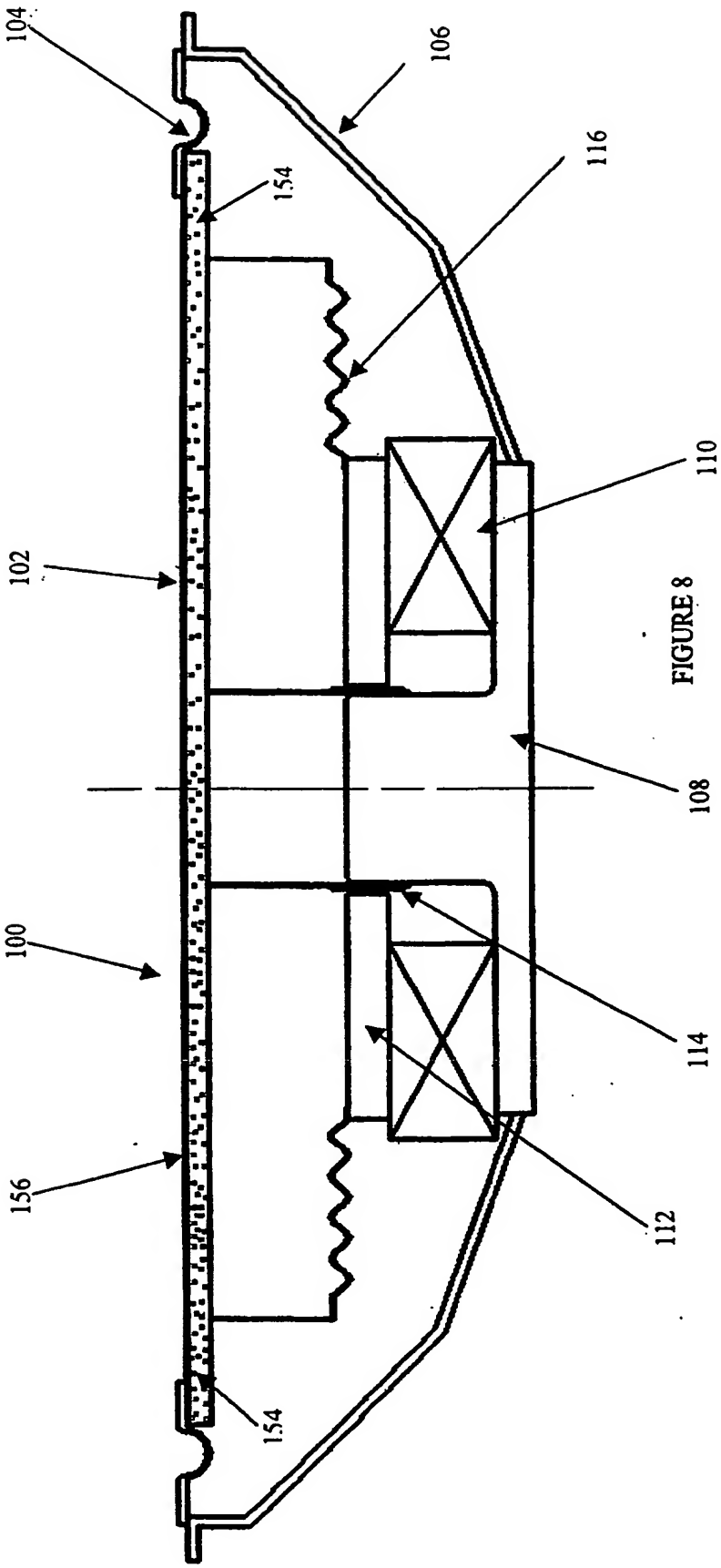

FIGURE 8

LOUDSPEAKER

This invention relates to loudspeakers, to their component parts and to the manufacture of such components.

The design of loudspeakers, especially for high-volume applications such as motor vehicle audio systems, is a compromise between acoustic performance and cost. Both are a function of the physical characteristics (stiffness, damping and weight) of the loudspeaker diaphragm. Conventionally loudspeaker diaphragms are made of specialist paper or fibre-based materials in order to achieve acceptable stiffness and damping without an excessive weight penalty. Excessive weight in the diaphragm is particularly undesirable because the speaker then requires more electrical power to produce a given acoustic output, necessitating a more powerful magnet and a more powerful amplifier, both of which increase the cost. Attempts to use plastics materials instead of paper have encountered difficulties that, if the plastics material is made thin enough to avoid excessive weight, the acoustic performance is unacceptable.

One preferred embodiment of the present invention addresses this problem, although the invention can be applied to other loudspeaker parts as well.

The invention provides in one aspect a loudspeaker component formed as a one-piece moulding in a single material, in which at least one portion of the component is of hollow material (as herein defined) and at least one other portion is of solid material.

By "hollow" we mean either hollow in the usual sense, i.e.

having an internal void, or having an internal cellular structure formed e.g. by foaming. The cellular structure can itself contain voids. As stated, the component may be a loudspeaker diaphragm, and the hollow portion may be positioned to modify the acoustic performance of the diaphragm.

The hollow portion, especially if of internally foamed or cellular construction can be significantly stiffer than a solid portion of the same weight, depending on the choice of material. Alternatively, if of flexible material it can provide high damping.

The hollow portion may be positioned to suppress bell-mode resonances of the diaphragm. Thus the hollow portion may be annular, and may be radially inward of the edge of the diaphragm and centred on the axis of the diaphragm. This configuration may be particularly suitable for elliptical diaphragms. Whilst usually the diaphragm will be generally conical in form, and cirular or elliptical in plan, it is also possible that the diaphragm may be made generally flat, and/or have a perimeter of a shape other than circular or elliptical.

The hollow portion may be disposed around the periphery of the diaphragm, and may constitute a surround integrally formed with the diaphragm, and provided with a peripheral flange for mounting the diaphragm to a chassis of the loudspeaker.

Alternatively or in addition, the hollow portion may be a radially-extending hollow rib. Such ribs normally would be angularly spaced around the diaphragm. The diaphragm-surround with its solid flange may be formed on its own as

a separate component. The diaphragm-surround may comprise a circumferentially-extending hollow portion which is substantially arcuate in radial cross-section.

The loudspeaker component according to the invention may be a diaphragm-surround or a voice-coil suspension.

The suspension may be apertured to permit the passage of air though it.

The suspension may have a radial cross-section which at least in part is serpentine in form, at least a portion of which is of said hollow material.

Whilst the invention is seen as of particular value for dynamic speaker components, it can be applied also to structural parts of the speaker. Thus the invention may also be applied to a loudspeaker chassis. The resulting component can be notably lighter than a comparable metal chassis or indeed a solid plastics chassis of comparable stiffness.

The said portion of hollow material may have a foamed interior and an unfoamed skin.

The component may be formed of a material exhibiting significantly less damping than polypropylene, such as ABS or polycarbonate.

The invention also provides a method of manufacturing a component as set forth above, which includes injecting said material into a mould tool having parts defining a first gap corresponding to the solid portion of the component, and

parts at least one of which is moveable defining a second gap corresponding to the hollow portion of the component, subsequently withdrawing the moveable part of the mould tool to increase the second gap, and expanding the material into the increased gap by foaming or blowing to form the hollow portion of the component.

The method may also comprise reducing a gap defined in the mould tool after the gap has received said material.

The invention will now be described merely be way of example with reference to the accompanying drawings, wherein:

Figure 1 shows the component parts of a loudspeaker, in an exploded view;

Figures 2A and 2B respectively show part of a conventional loudspeaker diaphragm-surround and part of a diaphragm-surround according to the invention, both in radial cross-section;

Figures 3A and 3B respectively show part of a conventional loudspeaker suspension and part of a loudspeaker suspension according to the invention, both in radial cross-section;

Figures 4A and 4B respectively show plan and perspective views of a loudspeaker diaphragm according to the invention;

Figure 5 shows another diaphragm according to the invention;

Figure 6 shows bell-mode resonance in a speaker diaphragm;

Figure 7 is a section through a speaker component according

to the invention; and,

Figure 8 is a section through a loudspeaker having a flat diaphragm according to the invention.

Referring to Figure 1, a loudspeaker consists principally of a frusto-conical diaphragm 10 having a surround 12 by which it is affixed to an outer ring 13 of a chassis 14 by adhesive together with a front gasket 18, card ring 20 and rear gasket 22. Registering holes 16 permit the speaker to be screwed to a vehicle door or loudspeaker cabinet.

The outer ring of the chassis is joined by webs 24 to an inner ring 26. An inner margin of the diaphragm 10 is connected to a bellows-like voice-coil suspension 28. In this embodiment the voice-coil suspension 28 also is attached to the inner ring 26 of the chassis. A small secondary diaphragm 29 with an internal dome can be fitted at the inner margin of the diaphragm 10 to augment its high frequency performance.

A voice coil former 30 carrying a voice coil is attached to the inner margin of the diaphragm 10 and extends rearwardly into a magnetic gap formed in a magnetic circuit consisting of a top plate 32, magnet 34 and pole plate 36. The ends of the voice coil are taken to a connector 38, to which an audio signal is supplied for operation of the speaker.

All parts except the connector 38 are of course arranged coaxially on the axis of the diaphragm 10. The voice-coil suspension centres the voice-coil 30 in the magnetic gap.

Referring to Figure 2A, in a conventional loudspeaker the

diaphragm-surround 12 can be of elastomeric material. Such surrounds are waterproof (important in loudspeakers for installation in a vehicle door), of consistent performance, and reliable. They also can be moulded directly onto the diaphragm 10, thus eliminating the need for adhesive. However, they are too heavy, and provide poor damping.

In Figure 2B the diaphragm-surround 12 comprises edge flanges 40, 42, the former being moulded to the diaphragm, the latter being for attachment to the outer ring of the chassis 14 as already described. The flanges 40 are of solid plastics elastomeric or resilient polymeric material. Between them, and moulded in the same material at the same time, is an arcuate section 44 of foamed construction. This foamed section provides greater damping than the conventional surround, and is also lighter in weight. If desired, different regions of the arcuate portion 44 may be provided with different degrees of foamed construction, or the arcuate portion may be foamed in discrete spaced-apart regions with solid regions in between.

Referring to Figure 3A, the suspension or spider 28 of Figure 1 is shown in radial half-section. It conventionally is of resin-impregnated cloth material, and is of bellows-like configuration so as to be of serpentine cross-section.

Resin-impregnated spiders deteriorate over time due to work hardening and fatigue cracking of the resin as the diaphragm vibrates. Elastomeric spiders can be moulded to the correct shape but are not sufficiently dimensionally stable over time which is a serious disadvantage in that the voice coil is a close fit in the magnetic gap, and must be accurately located radially and axially if contact with the magnet, the

top plate or the pole plate is to be avoided. A peripheral flange 46 is provided for attachment to the chassis inner ring 26, and the inner margin 48 is moulded or fixed with adhesive to the inner rim of the diaphragm 10 or voice coil former 30.

In Figure 3B, in a suspension or spider according to the invention, the peripheral flange 46 is of solid material, but the corrugated portion 50 is of foamed construction. The spider is formed as a single-piece moulding as described later. A suitable material is polyester.

The foamed portion may be continuous around the spider, or may be intermittent and interspersed with unfoamed (solid) sections. Suitable configurations of foamed and solid parts can be determined by known vibration simulation and finite element analysis techniques, to result in a light, well-damped component with excellent "run-in" characteristics ie. it does not change in stiffness during the life of the speaker. Holes 52 are provided at intervals through the spider so that air can pass through it, thereby reducing acoustic distortion which may occur if the spider is air-tight. Although shown as lying in the same sectional place in Figure 3B, it may be found advantageous to the acoustic performance of the suspension if the holes 52 are angularly staggered.

It is important that in operation the diaphragm responds to the input acoustic signals by vibrating coherently and not "breaking-up", which would introduce distortion. Thus the diaphragm 10 may also be formed as a single-piece moulding with solid and hollow portions to modify its acoustic performance. For example, as shown diagrammatically in Figure

4, radially extending ribs 54 of foamed and/or internally voided material are equiangularly spaced around a round diaphragm. The intervening portions of the diaphragm are of solid material. This configuration enables undesired resonances to be suppressed, especially with shallow diaphragm shapes. The diaphragm-surround 12 can conveniently be moulded onto the diaphragm or possibly could be moulded integrally with it at the same time in the same mould, but using different materials. This technique is known per se in other fields such as computer key pads.

In Figure 5 is shown diagrammatically an elliptical frusto-conical diaphragm provided with a foamed or otherwise hollow portion 56 in the form of a ring intermediate its inner and outer mar-gins 58, 60. The ring 56 can be dimensioned as positioned to suppress bell-mode resonance, in which, as illustrated diagrammatically in Figure 6, an acoustic-frequency wave 62 travels around the periphery of the diaphragm. An intermediate ring may be employed also in a round diaphragm, and radial ribs may be employed in an elliptical one. Both may be employed together in either shape of diaphragm.

A suitable material for a diaphragm according to the invention is ABS or polycarbonate, which has lower material damping than the polypropylene used hitherto. It also can be adhered better to other parts, and has better resistance to high temperatures, to which it may be exposed when attaching the surround, suspension or voice coil former. Another possible material is polyester.

The hollow regions moulded into the diaphragm enable the necessary damping and stiffness to be provided where

required with less reliance on the physical properties of the diaphragm material per se. Careful positioning of the hollow regions permits the production of diaphragms in plastics material which are lighter and shallower than hitherto, without the disadvantages of poor acoustic performance.

The speaker chassis may also be moulded to have hollow and solid parts according to the invention. Thus, for example, the web 24 of the chassis may have a cross-section as shown in Figure 7. The web has an outer unfoamed skin 64, an inner region 66 of foamed material and a central void 68. A light but rigid structure results.

Loudspeaker components according to the invention may be manufactured in accordance with one or more of the methods described in United Kingdom specifications 2308090 and 2321872, or International specifications WO98/16364 and WO98/17456. The disclosures of these specifications are incorporated herein by reference. Basically these methods include the steps of injecting moulding material into a die having a first gap or cavity defining what will be the solid part of the component, and a second gap corresponding to the hollow part. The second gap is bounded by a moveable part of the die which is withdrawn a predetermined distance after the material is injected. The material is expanded into the enlarged die cavity, either by foaming if a foaming agent is included in the material, or by blowing with an externally-supplied gas. In the latter case the resulting component does not have a foamed or cellular structure, but has an internal void. When a large degree of expansion is required, an internal void may form even when foaming rather than blowing is employed, resulting in the structure shown in

Figure 7. Blowing or foaming may be employed for any of the components described, as appropriate to their dimensions and properties required, and thus they may have either foamed or voided hollow portions, or both.

The hollow portion of the components will generally have an external skin as at 64, Figure 7. The thickness of this skin can be adjusted by controlling the temperature of the mould, and the time delay between injecting the material into the mould and withdrawing the moveable die part.

Figure 8 illustrates in section a loudspeaker 100 having a flat diaphragm (or piston) 102 formed according to the invention so as to have foamed and unfoamed portions for example as described for a conical diaphragm with reference to Figures 5 and 7. Figure 8 is a section through the flat diaphragm in a plane where it has radially-extending foamed ribs 154 on a relatively thin solid membrane 156. A surround 104 connects the periphery of diaphragm 102 to the edge of chassis (or frame) 106. Central of the chassis 106 is a pole plate 108, and a magnet 110 is held between pole plate 108 and top plate 112. A voice coil 114 is surrounded on one side by pole plate 108 and on the other side by magnet 110 and top plate 112. The voice coil 114 is wound on one end of a former that connects to diaphragm 102. A suspension (spider) 116 extends between the magnet 110 and diaphragm 102. This suspension may be as discussed with reference to Figure 3b.

In order to achieve a thin section in material containing a significant proportion of a filler such as talc, a technique may be adapted wherein the material is injected with the mould slightly open, or with a moveable part defining the

thin section slightly withdrawn so as to define a larger gap. This enables the gap to be properly filled with material. Then the die is closed or the moveable part is advanced to define the thin section, excess material being squeezed out to other parts of the mould. Then the previously-described moveable part defining the hollow portion of the component is withdrawn to permit foaming or blowing of the material.

Each feature disclosed in this specification (which term includes the claims) and/or shown in the drawings may be incorporated in the invention independently of other disclosed and/or illustrated features.

Statements in this specification of the "objects of the invention" relate to preferred embodiments of the invention, but not necessarily to all embodiments of the invention falling within the claims.

The text of the abstract filed herewith is repeated here as part of the specification. A loudspeaker component formed as a one-piece moulding in a single material, in which at least one portion of the component is of hollow material (as herein described) and at least one other portion is of solid material. The hollow portions may be positioned in an acoustically active component to control the acoustic performance of the component.

CLAIMS:

1. A loudspeaker component formed as a one-piece moulding in a single material, in which at least one portion of the component is of hollow material (as herein defined) and at least one other portion is of solid material.

2. A component as claimed in claim 1, being a loudspeaker diaphragm.

3. A component as claimed in claim 2, wherein the at least one hollow portion is positioned to modify the acoustic performance of the diaphragm.

4. A component as claimed in claim 3, wherein the at least one hollow portion is positioned to suppress bell-mode resonance of the diaphragm.

5. A component as claimed in claim 2, comprising a radially-extending hollow rib as said at least one portion.

6. A component as claimed in claim 2, wherein the at least one hollow portion is annular.

7. A component as claimed in claim 6, wherein the at least one hollow portion is disposed at the periphery of the diaphragm.

8. A component as claimed in claim 6, wherein the at least one hollow portion is disposed radially inwardly of the periphery of the diaphragm.

9. A component as claimed in claim 2, wherein the dia-

phragm is generally circular or elliptical in plan.

10. A component as claimed in claim 2, wherein the diaphragm is generally flat.

11. A component as claimed in claim 1, being a loudspeaker diaphragm-surround.

12. A component as claimed in claim 11, wherein the surround comprises a circumferentially extending hollow portion which is substantially arcuate in radial cross-section.

13. A component as claimed in claim 1, being a loudspeaker voice coil suspension.

14. A component as claimed in claim 13, wherein the suspension is apertured to permit the passage of air though it.

15. A component as claimed in claim 13, wherein the suspension has a radial cross-section which at least in part is serpentine in form, at least a portion of which is of said hollow material.

16. A component as claimed in claim 1, being a loudspeaker chassis.

17. A component as claimed in claim 1, wherein said portion of hollow material has a foamed interior and an unfoamed skin.

18. A component as claimed in claim 1, being made of a material exhibiting significantly less damping than polypropylene.

19. A component as claimed in claim 18, wherein the material is ABS or polycarbonate.

20. A method of manufacturing a component as claimed in claim 1, including injecting said material into a mould tool having parts defining a first gap corresponding to the solid portion of the component, and parts at least one of which is moveable defining a second gap corresponding to the hollow portion of the component, subsequently withdrawing the moveable part of the mould tool to increase the second gap, and expanding the material into the increased gap by foaming or blowing to form the hollow portion of the component.

21. A method as claimed in claim 20, also comprising the step of reducing a gap defined in the mould tool after the gap has received said material.

22. A loudspeaker comprising a component as claimed in claim 1.

23. A loudspeaker, a loudspeaker component or a method of manufacturing a loudspeaker component, substantially as herein described.

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Claims searched: All
Examiner: Geoff Holmes
Date of search: 16 May 2001

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

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Int Cl (Ed.7): H04R 7/02 7/04 7/06 7/12 9/00 9/02 9/06 31/00

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	EP 0944292 A2	[PIONEER] see fig 1 and col 3 lines 5-19	1 & 2 at least
X P	DE 10010491 A1	[PIONEER] see abstract and figs 4a-4c	1 & 2 at least
X	JP 580043699 A	[MATSUSHITA] see abstract and fig 1	1 & 2 at least
X	JP 560023097 A	[MATSUSHITA] see abstract and fig 2	1 & 2 at least
X	US 5793002 A	[SATO et al] see fig 1 and col 3 lines 32-40	1 & 2 at least
X	US 4395597 A	[KIYOAKI et al] particularly col 4 lines 7-19	1 & 2 at least

X Document indicating lack of novelty or inventive step
Y Document indicating lack of inventive step if combined with one or more other documents of same category.
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P Document published on or after the declared priority date but before the filing date of this invention.
E Patent document published on or after, but with priority date earlier than, the filing date of this application.

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